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Currency Misalignments and Growth: A New Look using Nonlinear Panel Data Methods

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CURRENCY MISALIGNMENTS AND GROWTH: A NEW LOOK USING NONLINEAR PANEL DATA METHODS

NON-TECHNICAL SUMMARY

There has recently been a revival of interest in equilibrium exchange rates' assessment due to the current context of global imbalances. Indeed, since the end of the 1990s, the accelerating financial integration process accompanied with the preeminence of capital movements over trade in goods between countries, has engendered a growing disconnection between exchange rate fluctuations and the real economic activity.

In this context, it seems particularly interesting to focus on the impact of currency misalignments on growth since persistent real exchange rate gaps are likely to affect the economic performance of countries. Indeed, persistent misalignments may induce distortions in relative prices of traded over non-traded goods that may be misinterpreted by economic agents and, as a consequence, may generate instability. In addition, the effects may be differentiated in case of an over- or under-valuation of currencies. If the currency is undervalued, competitiveness is reinforced, which stimulates domestic production, investment and exports, and reduces imports. The current account is then improved, so are GDP and employment. Conversely, currency overvaluations are rather interpreted as proofs of incoherent macroeconomic policy decisions, point to an increasing probability of balance of payment crises and of possible currency crashes, and contribute to deteriorate growth.

Our aim in this paper is to investigate the relationship between real exchange rate misalignments and economic growth, by paying a special attention to the potential differentiated effects of overvaluations and undervaluations. To this end, we specifically account for the sign (and the size) of the misalignment by estimating a panel nonlinear model. More specifically we rely on the estimation of a Panel Smooth Transition Regression (PSTR) model, allowing for a differentiated impact of currencies' overvaluations and undervaluations on economic growth. Moreover, while most of the previous studies consider developing countries, we rely on a wider sample of countries, including both developed and developing economies. Furthermore, we conduct a detailed analysis to derive robust measures of currency misalignments by relying on the Behavioural Equilibrium Exchange Rate (BEER) methodology.

Our results show that the impact of exchange rate misalignments on economic growth depends on their sign: there exists a positive and significant relationship between growth and exchange rate misalignment when the currency is undervalued, whereas overvaluations negatively affect economic growth. This re-

sult would imply that undervaluations, which could be attributed to competitive devaluations, may drive the exchange rate to a level that encourages exports and promotes growth.

ABSTRACT

The aim of this paper is to investigate the link between currency misalignments and economic growth. Relying on panel cointegration techniques, we calculate real exchange rate (RER) misalignments as deviations of actual RERs from their equilibrium values for a set of advanced and emerging economies. Estimating panel smooth transition regression models, we show that RER misalignments have a differentiated impact on economic growth depending on their sign: whereas overvaluations negatively affect economic growth, real exchange rate undervaluations significantly enhance it. This result indicates that undervaluations may drive the exchange rate to a level that encourages exports and promotes growth.

JEL Classification: F31, O47, C23.

Keywords: growth, exchange rate misalignments, nonlinearity, PSTR models.

MÉSALIGNEMENTS DE CHANGE ET CROISSANCE : L'APPORT DES MODÈLES NON LINÉAIRES EN PANEL

RÉSUME NON TECHNIQUE

L'évaluation de valeurs d'équilibre des taux de change a récemment connu un regain d'intérêt, en raison notamment du contexte actuel de déséquilibres mondiaux. Depuis la fin des années 1990, en effet, l'accélération du processus d'intégration financière a conduit à une certaine déconnexion entre les fluctuations de taux de change et l'activité économique réelle.

Dans un tel contexte, il semble particulièrement pertinent de s'intéresser à l'impact des mésalignements de change sur la croissance économique, dans la mesure où leur persistance est susceptible d'affecter la performance économique des pays. En effet, les mésalignements durables peuvent induire des distorsions dans les prix relatifs des biens échangeables par rapport aux biens non échangeables, pouvant, en conséquence, générer une certaine instabilité. En outre, les effets peuvent être différenciés en cas de sous-évaluations et de surévaluations des devises. Si la monnaie est sous-évaluée, la compétitivité est accrue, ce qui stimule la production nationale, l'investissement et les exportations, et réduit les importations. Il s'ensuit une amélioration du solde courant, du PIB et de l'emploi. Au contraire, les surévaluations reflètent généralement une certaine incohérence des décisions de politique macroéconomique, conduisant à une augmentation de la probabilité d'apparition de crises de balances des paiements et de change, contribuant ainsi à détériorer la croissance économique.

Notre objectif est d'étudier empiriquement ce lien entre les mésalignements de change et la croissance économique, en accordant une attention particulière aux effets différenciés des surévaluations et sous-évaluations. A cette fin, nous prenons spécifiquement en compte le signe (et la taille) du mésalignement en estimant un modèle non-linéaire en panel. Plus précisément, nous estimons un modèle à transition lisse (PSTR), ce qui permet de tenir compte d'un impact différencié des sous-évaluations et des surévaluations sur la croissance économique. Par ailleurs, alors que la plupart des travaux antérieurs considèrent uniquement les pays en développement, notre échantillon est composé de pays développés et émergents. De plus, nous menons une analyse approfondie afin de déterminer des valeurs robustes de mésalignements de change en recourant à l'approche comportementale du taux de change d'équilibre (BEER).

Nos résultats montrent que l'impact des mésalignements de change sur la croissance économique dépend de leur signe : il existe une relation positive et significative entre la croissance et les mésalignements lorsque la devise est sous-évaluée, alors que les surévaluations affectent négativement la croissance. Ce résultat indique que les sous-évaluations peuvent conduire le taux de change à un niveau qui stimule les exportations et, par là même, la croissance.

RÉSUMÉ COURT

L'objectif de cet article est d'étudier le lien entre les mésalignements de change et la croissance économique. En recourant aux techniques de cointégration en panel, nous estimons les mésalignements, définis comme l'écart des taux de change observés à leur valeur d'équilibre, pour un ensemble de pays développés et émergents. L'estimation de modèles non-linéaires à transition lisse nous permet de mettre en évidence que les mésalignements ont un impact différencié sur la croissance selon leur signe : alors que les surévaluations affectent négativement la croissance, les sous-évaluations tendent à la stimuler. Ce résultat indique que les sous-évaluations peuvent conduire le taux de change à un niveau qui stimule les exportations et, par là même, la croissance.

Classification JEL : F31, O47, C23.

Mots clés : croissance, mésalignements de change, non-linéarité, modèles PSTR.

Currency Misalignments and Growth: A New Look using Nonlinear Panel Data Methods[1]

Sophie Béreau*, Antonia López Villavicencio†, and Valérie Mignon‡

1. Introduction

There has recently been a revival of interest in equilibrium exchange rates' assessment due to the current context of global imbalances. Indeed, since the end of the 1990s, the accelerating financial integration process accompanied with the preeminence of capital movements over trade in goods between countries, has engendered a growing disconnection between exchange rate fluctuations and the real economic activity.

In order to better understand the sources of exchange rate movements, it may be useful for monetary authorities to rely on specific tools allowing assessment of long-run values for the real exchange rates that would be consistent with the realization of a long-run stable macroeconomic equilibrium. For that purpose, numerous "equilibrium exchange rate" concepts have been developed. Among the most popular approaches, there are the "Fundamental Equilibrium Exchange Rate" (FEER), the "NATural Real Exchange Rate" (NATREX) and the "Behavioral Equilibrium Exchange Rate" (BEER), respectively introduced by Williamson (1985), Stein (1994) and Clark and MacDonald (1998). Various other alternative approaches of equilibrium exchange rates have also been proposed in the literature. They all go beyond standard concepts of uncovered interest parity or purchasing power parity, and differ in their methodology and in the time horizon they deal with.[2]

If numerous contributions have explored the links between exchange rate volatility on different

[1]We thank Agnès Bénassy-Quéré and Jacques Melitz for very useful and stimulating remarks and suggestions.
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[2]For an extensive survey, see Driver and Westaway (2004).

exchange rate regimes and growth[3], the influence of long-run exchange rate misalignments[4] on real economic activity remains an open question. Yet, it seems particularly interesting to focus on the impact of currency misalignments on growth since persistent real exchange rate gaps are likely to affect the economic performance of countries. Indeed, persistent misalignments may induce distortions in relative prices of traded over non-traded goods that may be misinterpreted by economic agents and, as a consequence, may generate instability (see e.g. Edwards (1989)).

In addition, the effects may be differentiated in case of an over- or under-valuation of currencies. If the currency is undervalued, competitiveness is reinforced, which stimulates domestic production, investment and exports, and reduces imports (see, among others, Bresser-Pereira (2002) and Dooley et al. (2005)). The current account is then improved, so are GDP and employment. Conversely, currency overvaluations are rather interpreted as proofs of incoherent macroeconomic policy decisions (Razin and Collins (1997)), point to an increasing probability of balance of payment crises and of possible currency crashes (Krugman (1979), Frankel and Rose (1996), Kaminsky and Reinhart (1999) and Loayza et al. (2004)), and contribute to deteriorate growth.

The interest of studying the link between currency misalignments and growth is particularly notable for China. Chinese authorities have been frequently accused of maintaining the value of the yuan against major currencies at a very low level to finance China's spectacular growth. Among other things, such long-lasting misalignment would facilitate China's exports and thus economic growth. As Eichengreen (2008) mentions, "a competitive real exchange rate is at the heart of the authorities' development strategy". It should be noted that this exchange rate policy has a great effect not only on the Chinese economy but also on other countries. Indeed, the export-led growth has generated surging Chinese current account surpluses, creating a major source of tension among trading partners who experienced important current account deficits with China (especially the United States and the European union).

Among empirical studies dealing with the misalignment-growth nexus, many papers find a negative link between currency misalignments and economic growth in developing countries. This is the case of Ghura and Grennes (1993) showing a negative correlation between currency misalignments and 33 Sub-Saharan African countries' economic performance. As noticed by Cot-

[3]Among them, we can mention the seminal paper of Baxter and Stockman (1989), and more recently those of Levy-Yeyati and Sturzenegger (2003); Husain et al. (2005); Dubas et al. (2005); Benhima (2008) or Aghion et al. (2009).

[4]The misalignment is defined as the deviation of the observed real exchange rate from its equilibrium level.

tani et al. (1990), persistent misaligned currencies tend to slow the development of agriculture in African countries, leading to a reduction of their food supply. In the same vein, Domaç and Shabsigh (1999), Benaroya and Janci (1999), Acemoglu et al. (2003), Loayza et al. (2004), Toulaboe (2006), or Gala and Lucinda (2006), obtain similar results on extended panels of emerging economies. Turning now to the noticeable contribution of Aguirre and Calderón (2005), the authors assume possible differentiated countries' behaviors depending on the size and/or sign of their currency misalignments. To account for this possibility, they estimate a standard growth equation on a large panel of emerging economies in which they introduce interaction variables to capture the potential asymmetric behavior of countries depending on their currency facing an over- or an under-valuation. They show that the wider the currency misalignment, the more negative the impact on growth is, and that low undervaluations may be growth-enhancing whereas overvaluations will systematically produce a welfare loss. Studying Latin American countries, Frenkel (2004) finds that the overvaluation of their currencies constitutes one of the main explanation of crises and stagnation affecting these countries during the 1990s and 2000s.[5] The importance of accounting for the sign of the misalignment is also highlighted by Polterovich and Popov (2004) showing the existence of a positive relationship between economic growth and undervalued currencies. Relying on the endogenous growth literature, those authors argue that accumulation of foreign exchange reserves allows a country to keep an undervalued currency[6], inducing a rise in the aggregate demand, stimulating technological innovations and improving productivity growth in the export sectors, increasing profits in the non-tradable sector and stimulating investment. On the whole, the export-led growth model is developed, and countries are rewarded with high economic growth.

The aim of this paper is to investigate the relationship between real exchange rate misalignments and economic growth, by paying a special attention to the potential differentiated effects previously described. Our contribution is threefold. First, while most of the previous studies consider developing countries, we rely on a wider sample of countries, including both developed and developing economies. Accounting for a large sample of countries is of particular importance in the current context of global imbalances, that calls for a consistent set of equilibrium exchange rates. Second, we conduct a detailed analysis to derive robust measures of currency misalignments by relying on the BEER methodology. In this sense, we go further than most of the existing literature investigating the link between currencies and economic growth

[5] See also Easterly (2001) and Loayza et al. (2004).

[6] When a currency is undervalued, monetary authorities may react to upward pressures on the exchange rate by expanding their own money supply to buy foreign currencies, leading to an accumulation of foreign exchange reserves. This explains why reserves accumulation is used as a proxy for undervalued exchange rates by Polterovich and Popov (2004).

based on PPP measures of exchange rates. Third, we specifically account for the sign (and the size) of the misalignment by estimating a panel nonlinear model. More specifically we rely on the estimation of a Panel Smooth Transition Regression (PSTR) model, allowing for a differentiated impact of currencies' overvaluations and undervaluations on economic growth.

The remainder of the paper is organized as follows. Section 2 outlines our methodology relating to (i) the estimation of currency misalignments, (ii) the choice of the growth determinants, (iii) the PSTR models aiming at accounting for potential differentiated impacts of exchange rate over- and under-valuations on economic growth. Section 3 briefly describes the data and Section 4 presents the results. Finally, Section 5 provides some concluding remarks.

2. Methodology

2.1. Estimation of currency misalignments

Most of the previous studies that aim at investigating the link between exchange rates and economic growth rely on PPP-based measures of misalignments (see Dollar (1992), Benaroya and Janci (1999), Easterly (2001), Loayza et al. (2004), Acemoglu et al. (2003)).[7] However, PPP is relevant only in the very long run (see Rogoff (1996)) and does not provide any insight of exchange-rate adjustments that would be consistent with world imbalances being unraveled. To circumvent these drawbacks, we rely here on the "Behavioral Equilibrium Exchange Rate" approach introduced by Clark and MacDonald (1998). This approach consists in estimating a long-term relationship between the real effective exchange rate and its fundamentals. In this sense, the equilibrium exchange rate is allowed to change over time, reflecting changes in economic fundamentals and domestic policies. Based on previous studies[8], we consider the following determinants of the real effective exchange rate: the net foreign asset position, a measure of relative productivity, and terms of trade. We expect a positive link between the real effective exchange rate and all those potential determinants. Indeed, the real effective exchange rate is expected to appreciate if (i) the net foreign asset position increases, due to implied net interest receipts, (ii) terms of trade follow an increasing trend, leading to an improvement of the trade balance, (iii) productivity in the tradable sector increases relative to the rest of the world, according to the Balassa-Samuelson effect.

[7] An exception is Gala and Lucinda (2006) who use real exchange rate corrections for productivity differentials. Cottani et al. (1990) also consider various determinants of real exchange rates for a sample of less developed countries. The latter study, however, does not control for usual determinants of economic growth when evaluating the impact of the currency misalignments on the economic performance.

[8] See Bénassy-Quéré et al. (2008) for a review of possible specifications.

We estimate the following relationship:

$$q_{i,t} = \alpha_i + \beta_1 nfa_{i,t} + \beta_2 tot_{i,t} + \beta_3 prod_{i,t} + \varepsilon_{i,t} \tag{1}$$

where $i = 1, ..., N$ denotes the country, and $t = 1, ..., T$ the time. $q_{i,t}$ denotes the real effective exchange rate (in logarithms), $nfa_{i,t}$ is the net foreign asset position expressed as percentage of GDP, $tot_{i,t}$ is the logarithm of terms of trade, and $prod_{i,t}$ stands for the relative productivity in the traded-goods sector (relative to the non-traded goods one) in logarithms. $\varepsilon_{i,t}$ is an error term and α_i accounts for country-fixed effects. The estimation of Equation (1) gives the real equilibrium exchange rate values ($\hat{q}_{it}$) for each considered country. Misalignments $m_{i,t}$ are then obtained as:

$$m_{i,t} = q_{i,t} - \hat{q}_{i,t} \tag{2}$$

To estimate Equation (1), we rely on panel cointegration techniques. We first test for the existence of a unit root for each series using various panel unit root tests and then proceed to panel cointegration tests. If series are found to be cointegrated, we estimate the long-term relationship (1) using an efficient estimation procedure, such as Fully-Modified OLS (FM-OLS, see Phillips and Hansen (1990), Pedroni (1999) and Pedroni (2000)), Dynamic OLS (DOLS, see Kao and Chiang (2000) and Mark and Sul (2003)) or Pooled Mean Group (PMG, see Pesaran et al. (1999)).

2.2. Augmented growth equation

To investigate the impact of currency misalignments on economic growth, we add misalignment measures to the right-hand side variables that are usually considered in growth equations. More specifically, not accounting for nonlinearities, we consider a model of the following form:

$$\Delta y_{i,t} = \mu_i + \Omega X_{i,t} + \theta m_{i,t} + u_{i,t} \tag{3}$$

where $y_{i,t}$ is the real GDP per capita, $X_{i,t}$ is a vector of contemporaneous and lagged values of growth determinants, $m_{i,t}$ denotes currency misalignments and $u_{i,t}$ is an error term. μ_i is a vector of individual fixed effects. Despite the vast number of cross-country growth studies that followed the seminal papers of Barro (1991) and Mankiw et al. (1992), there remains a broad number of possible specifications concerning the choice of the regressors. As mentioned by Sala-i Martin (1997), “Variables like the initial level of income, the investment rate, various measures of education, some policy indicators, and many other variables have been found to be significantly correlated with growth in regressions like (3). I have collected around 60 variables which have been found to be significant in at least one regression.” Indeed, due to the lack of consensus on the key determinants of growth, several regressors are used. They belong to various categories:[9] policy variables (fiscal, exchange rate and trade policies), political variables (rule of law, political rights, ...), religious variables, regional variables, type of investment (equipment/non equipment), variables relating to the macroeconomic environment (inflation—which is also a policy variable—, initial level of GDP, ...), variables accounting for the international environment (terms of trade, ...), etc.

Based on previous studies[10], we retain various usual determinants. According to the neoclassical growth theory, the economic growth rate is a function of the initial position of the economy. The conditional convergence hypothesis states that, other things being equal, countries with lower GDP per capita are expected to grow more due to higher marginal returns on capital stock. We account for the initial position of the economy through the initial level of real GDP per capita to control for conditional convergence (see Barro and Sala-i Martin (1995) among others). Turning to other variables that may characterize the specificities of the various considered countries, we consider a measure of human capital given by the rate of gross secondary-school enrollment (see Barro (1991), Mankiw et al. (1992) and Easterly (2001) among others). Relying on some developments of the endogenous growth theory, we include determinants reflecting trade policies, macroeconomic stabilization policies and institutions. Among those potential determinants, we consider the following variables: (i) trade openness (measured as the sum of exports and imports, in percentage of GDP)[11], (ii) government consumption in percentage of GDP, used as an indicator of fiscal policy (see Barro (1991); Barro and Sala-i Martin (1995)), (iii) fixed investment (in percentage of GDP), (iv) the inflation rate to account for price level stability and (v) population growth.[12] Finally, to these usual determinants, we add currency misalignments in order to investigate the impact of exchange rate overvaluations and undervaluations on economic growth.

2.3. Dealing with nonlinearities: the PSTR approach

Let $\{z_{i,t}, s_{i,t}, x_{i,t}; t = 1, ..., T; i = 1, \ldots, N\}$ be a balanced panel with $z_{i,t}$ denoting the dependent variable, $s_{i,t}$ the threshold variable, and $x_{i,t}$ a vector of k exogenous variables. The panel

[9]See Sala-i Martin (1997) for a complete list. See also Loayza et al. (2004) for a detailed review of the main determinants and studies on economic growth.

[10]See the reference papers by Barro (1991), Mankiw et al. (1992) and Sala-i Martin (1997), and Dufrénot et al. (2009) for a recent study.

[11]For a recent study of the trade-growth nexus, the reader may refer to Dufrénot et al. (2009).

[12]Note that we do not consider terms of trade, which allows to account for cross-country differences in the external environment, since this determinant is already included in our misalignment variable. As a robustness check, we have however dropped terms of trade from the cointegrating relationship and included them in the growth equation, see Subsection 4.3.3.

smooth transition regression (PSTR) model introduced by González et al. (2005)[13] can be written as follows:

$$z_{i,t} = \mu_i + \beta_0' x_{i,t} + \beta_1' x_{i,t} g\left(s_{i,t};\gamma,c\right) + v_{i,t} \quad (4)$$

where μ_i denotes the individual fixed effects, $g\left(s_{i,t};\gamma,c\right)$ is the transition function, normalized and bounded between 0 and 1, γ the speed of transition from one regime to the other and c the threshold parameter. The threshold variable $s_{i,t}$ may be an exogenous variable or a combination of the lagged endogenous one (see van Dijk et al. (2002)).

In this model, the observations in the panel are divided into two regimes[14] depending on whether the threshold variable is lower or larger than the threshold c. The error term $v_{i,t}$ is independent and identically distributed. The transition from one regime to another is smooth and gradual.

Following Granger and Teräsvirta (1993) and Teräsvirta (1994) in the time series context or González et al. (2005) in a panel framework, the logistic specification can be used for the transition function:

$$g\left(s_{i,t};\gamma,c\right) = \left[1 + \exp\left(-\gamma \prod_{j=1}^{m}\left(s_{i,t} - c_j\right)\right)\right]^{-1} \quad (5)$$

with $\gamma > 0$ and $c_1 \leq c_2 \leq ... \leq c_m$. When $m = 1$ and $\gamma \to \infty$, the PSTR model reduces to the panel threshold regression (PTR) model introduced by Hansen (1999), characterized by an abrupt change from one regime to the other. González et al. (2005) mention that from an empirical point of view, it is sufficient to consider only the cases of $m = 1$ or $m = 2$ to capture the nonlinearities due to regime switching.[15]

Following the methodology used in the time series context, González et al. (2005) suggest a three step strategy to apply PSTR models:[16]

- **Specification**. The aim of this step is to test for homogeneity against the PSTR alternative. To this end, we rely on the LM-test statistic provided by González et al. (2005) that can be

[13] See also He and Sandberg (2004) and Fok et al. (2005) who have introduced dynamic nonlinear panel models through the development of panel logistic smooth transition autoregressive models.
[14] Of course, it is possible to extend the PSTR model to more than two regimes.
[15] Note that the case $m = 1$ corresponds to a logistic PSTR model and $m = 2$ refers to a logistic quadratic PSTR specification.
[16] See also Béreau et al. (2008).

used to select (i) the appropriate transition variable as the one that minimizes the associated p-value and (ii) the appropriate order m in Equation (5) in a sequential manner.

- **Estimation**. Nonlinear least squares are used to obtain the parameter estimates, once the data have been demeaned.
- **Evaluation and choice of the number of regimes**. We apply misspecification tests in order to check the validity of the estimated PSTR model. We follow González et al. (2005) who propose to adapt the tests of parameter constancy over time and of no remaining nonlinearity introduced by Eitrheim and Teräsvirta (1996) in the time series context.

On the whole, putting together Equations (3) and (4), our considered model of growth is given by:

$$\begin{aligned}\Delta y_{i,t} =& \mu_i + \underbrace{\Omega_1 X_{i,t} + \theta_1 m_{i,t}}_{\text{Regime 1}} + \\ & \Big[\underbrace{\Omega_2 X_{i,t} + \theta_2 m_{i,t}}_{\text{Regime } 2_{-1}}\Big] g\left(s_{i,t}; \gamma, c\right) + u_{i,t}\end{aligned} \tag{6}$$

Depending on the realization of $s_{i,t}$, the link between $\Delta y_{i,t}$ and its determinants will be specified by a continuum of parameters, namely Ω_1 and θ_1 in Regime 1 (when $g(.) = 0$), and $\Omega_1 + \Omega_2$ and $\theta_1 + \theta_2$ in Regime 2 (Regime 1 + Regime 2_{-1}) when $g(.) = 1$. Our main threshold variable of interest will be the misalignment $m_{i,t}$ or its lagged values. If two distinct growth regimes are associated with the misalignment as threshold variable, this would mean that exchange rate over- and under-valuations have a different impact on economic growth. In other words, this model allows us to investigate if nonlinearity in economic growth could be associated with changes in the magnitude and sign of the misalignment.

3. DATA

To estimate our real misalignments and growth equations we use annual data over the 1980-2007 period for the following countries: Argentina, Australia, Brazil, Canada, Chile, China, Colombia, Costa Rica, Denmark, Egypt, United Kingdom, Hong-Kong, Indonesia, India, Israel, Japan, Korea, Mexico, Malaysia, Norway, New Zealand, Peru, Philippines, Singapore, Sweden, Switzerland, Thailand, Turkey, Uruguay, United States, Venezuela and the Euro area. Using such an extensive panel of both industrialized and emerging economies is a critical point to properly assess the impact of currency misalignments on growth. Indeed, if prior studies have focused either on developing countries or on developed ones, the need to derive consistent values of equilibrium exchange rates calls for a broader sample, including both types of economies. Bénassy-Quéré et al. (2008) have showed that the Group of Twenty could be a convenient framework to derive consistent equilibrium exchange rates according to the BEER approach. Here, we rely on a wider sample, by considering 32 countries (14 of them belonging to the G-20).

Regarding the long-run BEER equation, from which we derive our measures of currency misalignments, the dependent variable is the real effective exchange rate (q) and the explanatory variables are the stock of net foreign assets (nfa), the productivity differential proxied here by the relative labor productivity of tradables to non tradables ($prod$), and the terms of trade (tot). All series are in logarithms, except nfa which is expressed as share of GDP in percentage points.

The real effective exchange rate for each country i is calculated as a weighted average of real bilateral exchange rates against each j trade partner. Bilateral real exchange rates are derived from nominal rates and consumer price indices (CPI); they are based in 2000.[17] The weights have been calculated as the share of each partner in average values of imports and exports of goods and services over the 2000-2007 period.[18] Intra-Eurozone flows have been excluded and trade weights have been normalized to sum to one across the partners included in the sample.

Denoting the variables in logarithms in lower cases, we can write:

$$q_{i,t} = \sum_{j \neq i} \omega_{ij} \left(e_{i,t} - e_{j,t} \right) = \sum_{j \neq i} \omega_{ij} e_{ij,t} \text{ where } \sum_{j \neq i} \omega_{ij} = 1 \tag{7}$$

where $e_{i,t}$ denotes the real bilateral exchange rate of currency i vis-à-vis the USD, $e_{ij,t}$ the one against the j currency and ω_{ij} the trade weights. When $q_{i,t}$ rises (resp. falls), it corresponds to an appreciation (resp. depreciation) of currency i in effective terms.

The net foreign asset position is built using the Lane and Milesi-Ferretti database from 1980 to

[17]Source: World Bank *World Development Indicators* (WDI) for nominal exchange rates and CPI data except for the EUR/USD exchange rate which was extracted from Datastream and China's real exchange rate which was calculated with GDP deflator (WDI).

[18]Source: IMF *Direction of Trade Statistics* (DOTS). For robustness checks, we have considered two additional weighting schemes: average weights over the whole period and weights in 2007 (the last point of our sample). The results were very similar, and we only report those obtained using the weighting matrix based on the 2000-2007 mean trade flows.

2004.[19] To complete the database from 2005 to 2007, we rely on the information provided by IFS (*International Financial Statistics*, IMF) and WDI (*World Development Indicators*, World Bank) on gross foreign assets and liabilities by applying the corresponding growth rates first on 2004 gross values, and then by reconstruction, to both sides of the international investment position for each country of the panel. Finally, the net foreign asset positions are obtained by difference.[20] We do the same for the Euro zone aggregate for which no data were available before 1999. To correct for intra-zone flows before 1999, we assumed that the share of external wealth accumulation due to intra-zone financial flows was the same than that due to intra-zone trade flows. By doing so, we obtain figures that can be easily linked to Lane and Milesi-Ferretti's estimations over the 1999-2004 period.

Turning to the other explanatory variables, the terms of trade are excerpted from WDI, except for the Euro zone and Chile (IFS). Concerning the proxy for relative productivity, we use the relative labor productivity of tradables to non tradables, measured by output per worker. It is calculated on the basis of a dataset for output and employment for a 6-sector classification (or 3- sector when the 6-sector data were not available).[21]

Regarding now our growth equation, the dependent variable is the growth rate of real GDP per capita, extracted from the Penn World Table 6.1.[22] The explanatory variables are taken from IFS (inflation rate and government consumption), the Penn World Table 6.1 (real investment, trade openness—measured as the sum of exports and imports—and population growth), and the United Nations' database (gross-secondary school enrollment rate).

4. RESULTS

The first part of the analysis consists in the estimation of equilibrium exchange rates and the corresponding real effective misalignments for the 32 countries (or areas) of our sample. In

[19]Source: `http://www.imf.org/external/pubs/cat/longres.cfm?sk=18942.0`, see Lane and Milesi-Ferretti (2007).
[20]Source: IMF (IFS), February 2009, and World Bank (WDI).
[21]We rely on the IMF classification (see IMF (2006)). In the 6-sector classification, the tradable sector includes: agriculture, hunting, forestry, and fishing; mining, manufacturing, and utilities; and transport, storage, and communication. The non-tradable sector includes: construction; wholesale and retail trade; and other services. In the 3-sector classification, the tradable sector includes agriculture and industry. The sources are the following: the United Nations Statistics Division, International Labor Office Bureau of Statistics, Eurostat, World Bank and Groningen Growth and Development Centre.
[22]Alan Heston, Robert Summers and Bettina Aten, Penn World Table Version 6.1, Center for International Comparisons at the University of Pennsylvania (CICUP), October 2002.

a second step, a panel nonlinear model is estimated, linking the growth rate of real GDP per capita to our measure of currency misalignment and the set of our control variables.

4.1. Estimating equilibrium exchange rates

As revealed from panel unit root and cointegration tests, our series are integrated of order 1 and cointegrated.[23] We then proceed to the estimation of the long-run relationship between the real exchange rate and the explanatory variables. As previously mentioned, three main approaches exist to estimate a cointegrating relationship in a panel framework: the FM-OLS, DOLS and PMG estimators. Here we retain the PMG procedure proposed by Pesaran et al. (1999). This estimator combines two procedures that are commonly used in panels. The first one, known as the 'mean group estimate', consists in estimating separate relationships for each country (or group) and averaging the group specific coefficients. The second one is based on the traditional pooled estimators that allow only the intercepts to differ freely across countries, while all the other coefficients are constrained to be the same. The PMG estimator can be viewed as an intermediate estimator since it combines both pooling and averaging. Given that we are dealing with advanced and emerging economies, some degree of heterogeneity between countries would be recommended. In this sense, the advantage of the PMG estimation procedure over FM-OLS and DOLS techniques is that, while slope homogeneity is imposed (but can be tested by a Hausman-type test), short-run heterogeneity is allowed for each member of the panel.

Table 1 – PMG estimates for the equilibrium exchange rate equation

Variable	Coeff.	t-stat
Productivity (log)	0.187	3.271
NFA (% GDP)	0.177	5.022
Terms of trade (log)	0.155	4.716

The results from the panel cointegration estimation (Table 1) appear consistent with the theory since the coefficients have the expected signs. Indeed, the real exchange rate appreciates (q increases) in the long run if the net foreign asset position rises, the relative productivity increases, and the terms of trade improve.

As mentioned before, our theoretical measure of the real exchange rate misalignment, $m_{i,t}$, is defined as the difference between the actual real exchange rate and its equilibrium value ($m_{i,t} = q_{i,t} - \hat{q}_{i,t}$), as obtained from the cointegrating relationship. According to our definition,

[23] All the results are available upon request to the authors.

the currency is undervalued when the real exchange rate (RER) has to appreciate to reach its equilibrium value (i.e. when $q_{i,t} < \hat{q}_{i,t}$), and overvalued when the RER has to depreciate (i.e. when $q_{i,t} > \hat{q}_{i,t}$).

4.2. Estimating the nonlinear growth equation

We start by testing the null hypothesis of linearity in model (6) using, as the relevant transition variable, our derived series of misalignment. In other words, we test if there exists some difference in the response of growth to positive and negative RER misalignments and if the transition from one regime to another depends on the size and the sign of the deviation of the RER from its equilibrium level.

The results from a test based on a first-order Taylor series expansion of a nonlinear smooth transition regression (STR) model show that linearity can be rejected at the 5% significance level for our panel of countries.[24] We therefore proceed to the estimation of the nonlinear growth relationship (Equation (6)), using the growth rate in real GDP per capita as our dependent variable. As previously mentioned, for the explanatory variables we consider the initial value of the GDP per capita (in logarithms), the investment rate (as share of GDP), a measure of trade openness given by the sum of exports and imports (as share of GDP), average annual CPI inflation[25], government consumption (in proportion of GDP), the rate of gross-secondary school enrollment, population growth and real exchange rate misalignment.

A typical concern when dealing with growth regressions is relating to the short-run or cyclical effects. To control for cyclical output movements, a possible approach consists in averaging the data over time (typically, 5-year averages) and consider these averages of data series in the growth equation. While this method has the advantage to remove business cycles effects from the growth rate, it reduces considerably the number of degrees of freedom by diminishing the number of available observations for each country. This is of course especially true when the time period is short or when the frequency of the original data is low. To avoid this drawback, we consider here the dataset with annual observations without averaging over time periods, thus gaining a more comfortable number of observations (32 countries, 28 years).[26]

[24]Test results are available from the authors upon request.

[25]Denoting the inflation rate as $\pi_{i,t}$, we retain the following expression for inflation in the growth regression: $log(1 + \pi_{i,t})$. This choice may be notably justified by the fact that the logarithmic transformation reduces the asymmetry of the distribution of $\pi_{i,t}$—which is known to be highly skewed.

[26]Note that various studies, such as Christoffersen and Doyle (1998), Ghosh and Phillips (1998), Khan and Senhadji (2000) and Burdekin et al. (2004) among others, work with annual data instead of averaging as well. For robustness checks, we have also run our estimations on 5-year average series. Since the results were very similar,

In Table 2, we report the regression estimates of the PSTR model using a specification with a logistic transition function and two regimes.[27] When the transition variable (i.e. the misalignment) is below the estimated threshold parameter c in Equation (6), growth is defined by the estimated equation reported in Column (1) of Table 2. On the contrary, if the transition variable exceeds the threshold parameter, growth is defined by the sum of the estimates in Columns (1) and (2) of the table. Our results show that our estimated threshold is equal to -1.68%. This means that the first regime, characterized by $g(.) = 0$, corresponds to undervaluations more than 1.68%. The second regime, corresponding to $g(.) = 1$, is relating to overvaluations and small undervaluations, i.e. undervaluations less than 1.68%. There are, however, a continuum of points between these two extreme cases. This continuum is illustrated by Figure 1 which plots the transition function versus the transition variable. As shown, the transition function is quite smooth, with several points in each side of the threshold, but with a relative higher presence of observations below the threshold.

Table 2 – PSTR model for the growth rate of GDP per capita, with estimated transition function: $g(m_{i,t};\hat{\gamma},\hat{c}) = (1 + exp\{-8.9347(m_{i,t} + 0.0168)\})^{-1}$

	$g(.) = 0$		$g(.) = 1$	
	Coef.	t-stat	Coef.	t-stat
	(1)		(2)	
Real exchange rate misalignment	0.0558	2.0579	-0.0917	-3.5339
Inflation	-0.0499	-4.5349	0.0396	2.7006
Initial GDP per capita (log)	-0.0288	-4.9019	0.0018	1.2094
Investment (% of GDP)	0.0328	2.5931	0.0342	2.3419
Trade openness (% of GDP)	0.0245	3.8834	-0.0036	-0.5588

Let us first comment the results relating to the control variables. All the explanatory variables have the expected sign, whatever the sign and the size of the misalignment. Indeed, in both extreme regimes (i.e. when $g(.) = 0$ and $g(.) = 1$) the initial GDP per capita coefficient is negative, meaning that the conditional convergence hypothesis is evidenced: holding constant other growth determinants, countries with lower GDP per capita tend to grow faster. The ini-

we only report here our findings without averaging the series. More specifically, while the estimated coefficients may slightly differ between the two estimations (with and without averaging), their sign was always the same, leading thus to similar qualitative conclusions. All results are available upon request to the authors.

[27] Some of the variables have been excluded from the final estimation since they were not significant (see below). Also, the choice between a logistic and a logistic quadratic model was based on information criteria and the lowest p-value in the linearity tests.

tial position of the economy is thus a significant determinant of growth, as preconised by the neoclassical theory. As indicated before, we also included the rate of gross secondary-school enrollment as another characteristic of initial conditions, but this variable has been dropped from the final estimation since it was not significant. This result is in accordance with those of Romer (1989) and De Gregorio (1992) who report non significant impact of human capital proxy on growth. Turning to the other control variables, our findings show that the coefficient of the inflation rate is significantly negative, meaning that price instability tends to hamper growth. In other words, low inflation, as part of a broad macroeconomic stabilization policy, is an important condition to promote growth.[28] The investment variable has also the right sign since there exists a positive relationship between capital accumulation and growth. Trade openness also positively affects growth, a fact that is in line with both the neoclassical approach and the endogenous growth theory. Indeed, according to the former, the positive impact of trade on growth is explained by comparative advantages, be they in resource endowment or differences in technology. Turning to the endogenous growth literature, it asserts that trade openness positively affects growth through economies of scale and technological diffusion between countries. Finally, as predicted by the Solow growth model, the population growth coefficient is negative, but since it was not significant, the variable has been dropped from the equation.

Turning now to our main variable of interest, our results show that the misalignment has also the expected sign in the case of undervaluations. Indeed, in this first regime, the coefficient is equal to 0.056, meaning that, other things being equal, a depreciation of the real exchange rate of 10% contributes for an increase in GDP per capita growth of 0.56 percentage points. Undervaluations have thus a positive impact on economic growth, as expected. This result is consistent with those of Bresser-Pereira (2002), Aguirre and Calderón (2005) and Dooley et al. (2005) and illustrates the fact that competitiveness is reinforced when the currencies are undervalued. More importantly, our findings put forward a differentiated effect of real exchange rate misalignments on growth, depending on whether they reflect over- or under-valuations of the considered currency. Indeed, this impact varies between 0.56 pp. (Regime 1) and -0.36 pp. (Regime 2) on GDP per capita growth. In other words, while undervalued currencies stimulate growth, overvalued exchange rates hamper it. Put differently, the lower the overvaluations, the lower the negative impact on growth.

[28]Note that, as mentioned before, we have also introduced another proxy for fiscal policy, namely government consumption in percentage of GDP. Since the inclusion of this variable has led to very similar results, we have removed it from the final estimation (but results are available upon request to the authors). As expected, the sign of the coefficient was negative, reflecting the fact that the ratio of government consumption to GDP can be viewed as a proxy for the government burden (see Barro (1991), Barro and Sala-i Martin (1995) and Loayza et al. (2004) among others).

These results are illustrated in Figure 2, which depicts real exchange rate misalignment and its effect on growth (i.e. the elasticity). As it can be seen, the higher the size of undervaluations (values below the zero line), the higher the positive effect of misalignment on growth (see for example, Argentina between 2001 and 2007 or China after 1990). On the contrary, overvaluations have negative effects (see Mexico at the end of the period for instance).

This different impact of the exchange rate misalignment on growth clearly highlights the interest of our nonlinear specification and shows that exchange rate policy may play a key role in economic growth: appropriate exchange rate policies that limit currency overvaluation could be used to promote economic growth. On the whole, to boost growth, policymakers may undervalue their currencies.

4.3. Robustness checks

Our findings evidence a different impact of currency misalignments on economic growth, depending on the size and sign of the exchange rate deviation from equilibrium. Our results also show that control variables have the expected effects, since they are correctly signed. To test the robustness of our main conclusion regarding the effects of misalignments, we conduct some additional regressions, investigating the issues of nonlinear versus linear specifications, endogeneity, inclusion of terms of trade in the growth equation and choice of the misalignment measure.

4.3.1. Nonlinear versus linear growth equation

To put forward the interest of our nonlinear specification, we estimate a linear growth equation. Results reported in Table 3 indicate that all the control variables have the expected sign. Indeed, the initial GDP per capital level acts negatively on growth—as predicted by the conditional convergence hypothesis—and the effect of inflation is also negative—putting forward the importance of price stability in promoting growth. Investment and openness positively affect economic growth, as expected. Turning to our main variable of interest, our findings show that the coefficient of the exchange rate misalignment is negative: an overvalued currency tends to slow growth on average. However this result may cover a differentiated impact of an exchange rate appreciation depending on the initial misalignment—especially on whether the currency is overvalued or undervalued. To take this issue into account, a nonlinear specification is needed.

Table 3 – Linear growth equation (GMM estimation)

Variable	Coeff.	t-stat
Real exchange rate misalignment	-0.023	-2.51
Inflation	-0.019	-2.07
Initial GDP per capita (log)	-0.027	-3.07
Investment (% of GDP)	0.063	4.77
Trade openness (% of GDP)	0.039	3.82

4.3.2. Endogeneity issues

An important concern in growth regressions is the issue of endogeneity. Indeed, some of the explanatory variables, namely openness and fixed investment, could potentially be explained by common factors and, therefore, engender endogeneity problems that must be taken into account to avoid potential bias in the estimation results. Various methods exist to deal with the issue of endogeneity such as instrumental variables methodology, quantile regressions... (see Dufrénot et al. (2009) among others). Since trade openness and investment are not our main variables of interest here, we only proceed to robustness checks by instrumenting these two variables by their own lagged values. Using two lags for each variable, our estimations show that the effects of the misalignment on economic growth are highly similar to those obtained in Table 2. Indeed, we found that a depreciation of the real exchange rate of 10% increases the GDP growth by 0.56 pp, whereas a 10% appreciation reduces it by 0.32 pp. Our findings that undervaluations tend to enhance growth, while overvaluations have a negative impact are thus robust to endogeneity issues.

These findings can be linked to those of Aghion et al. (2009). As argued by the authors, our empirical analysis has some characteristics that reduce the potential endogeneity problem. Indeed, our aim is to put forward contrasting growth effects of misalignments for different levels and signs of the real exchange rate deviations from equilibrium. We are thus in presence of interaction terms that reduce the endogeneity bias (see Aghion et al. (2009) for more details). Moreover, similar results were obtained with the lagged values of control variables (see above) and with an alternative measure of misalignment (see below).

4.3.3. Terms of trade and misalignment measure

As previously indicated, terms of trade have not been included in the growth equation since this variable was used as a determinant of the real exchange rate in the cointegrating relationship. As a robustness check, we estimate a new misalignment series by dropping the terms of trade from the cointegrating relationship, and adding them into the growth equation. From a theoretical viewpoint, the direction of the impact of terms of trade on economic growth depends on the relative influence of substitution versus income effect. In case of a negative terms of trade shock, such as an increase in the price of imports, the relative price of nontradables falls due to the decrease in the permanent income together with the fall in the demand for nontradables, leading to an exchange rate depreciation. If the substitution effect dominates the income one, price of nontradables will increase, inducing a real appreciation.

Results reported in Table 4 justify our choice to consider terms of trade in the cointegrating relationship as a determinant of the real exchange rate rather than in the growth equation. Indeed, terms of trade are not significant in the growth equation at the 5% significance level, whereas this variable was significant in the long-term relationship. Anyway, terms of trade have a slight positive impact on economic growth (only significant at the 10% statistical level).

Table 4 – Robustness checks. PSTR model for the growth rate of GDP per capita, including terms of trade. Estimated transition function: $g(m_{i,t}; \hat{\gamma}, \hat{c}) = (1 + exp\{-4.8592(m_{i,t} - 0.1022)\})^{-1}$

	$g(.) = 0$		$g(.) = 1$	
	Coef.	t-stat	Coef.	t-stat
	(1)		(2)	
Real exchange rate misalignment	0.0650	2.6406	-0.0320	-1.5450
Inflation	-0.0340	-3.5864	0.0162	1.0745
Initial GDP per capita (log)	-0.0177	-3.1186	0.0017	0.9375
Investment (% of GDP)	0.0306	2.6417	0.0527	2.8430
Trade openness (% of GDP)	0.0304	4.7027	-0.0172	-2.2667
Terms of trade growth	0.0549	1.6755	0.0019	0.0294

As a final robustness check, we consider another misalignment measure. Instead of relying on fundamentals, we calculate the misalignment as the deviation of the actual real exchange rate from its Hodrick-Prescott detrended value as in Goldfajn and Valdes (1999) and Aghion et al. (2009). The filtered series represents the predicted equilibrium real exchange rate and captures the permanent changes in the series. As shown in Table 5, while the impact of some variables on economic growth may slightly differ from the results reported in Table 2—which is not surprising given that the misalignment series does not account for the fundamentals determinants of the exchange rate—our findings are qualitatively similar. In particular, the effect of currency misalignment on growth is positive in case of undervaluations and negative for overvaluations, confirming our previous findings.

Table 5 – Robustness checks. PSTR model for the growth rate of GDP per capita, HP equilibrium exchange rate. Estimated transition function: $g(m_{i,t};\hat{\gamma},\hat{c}) = (1 + exp\{-6.7630(m_{i,t} - 0.0714)\})^{-1}$

	$g(.) = 0$		$g(.) = 1$	
	Coef.	t-stat	Coef.	t-stat
	(1)		(2)	
Real exchange rate misalignment	0.2305	3.5192	-0.2792	-4.4140
Inflation	-0.0671	-4.8507	0.0981	4.2149
Initial GDP per capita (log)	-0.0253	-3.3529	0.0010	0.3754
Investment (% of GDP)	0.0113	0.7190	0.1033	3.2535
Trade openness (% of GDP)	0.0088	0.5723	0.0670	1.9770

5. CONCLUSION

Various empirical studies have investigated the importance of variables such as the initial level of GDP, investment, human capital, trade openness and population growth, in explaining economic growth. However, not much has been done regarding the importance of real exchange rate misalignments as a potential determinant of growth. Our aim in this paper is to fill this gap by paying a special attention to the influence of exchange rate over- and under-valuations on the economic growth for a large set of countries, including both developing and advanced economies.

To this end, by estimating panel smooth transition regression models, we show that the impact of exchange rate misalignments on economic growth depends on their sign. Indeed, we find that there exists a positive and significant relationship between growth and exchange rate misalignment when the currency is undervalued, whereas overvaluations negatively affect economic growth.

The previous result would imply that undervaluations, which could be attributed to competitive devaluations, may drive the exchange rate to a level that encourages exports and promotes growth. On the contrary, overvaluations discourage economic growth. These findings show that exchange rate policy may play a key role in economic growth and suggest that to boost performance, policymakers may undervalue their currencies.

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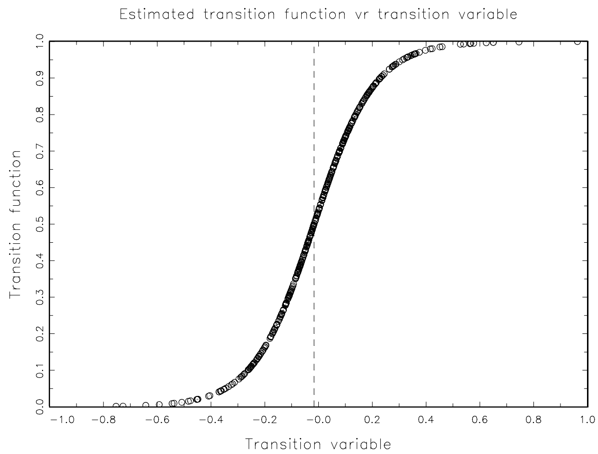

Figure 1 – Estimated transition function versus transition variable

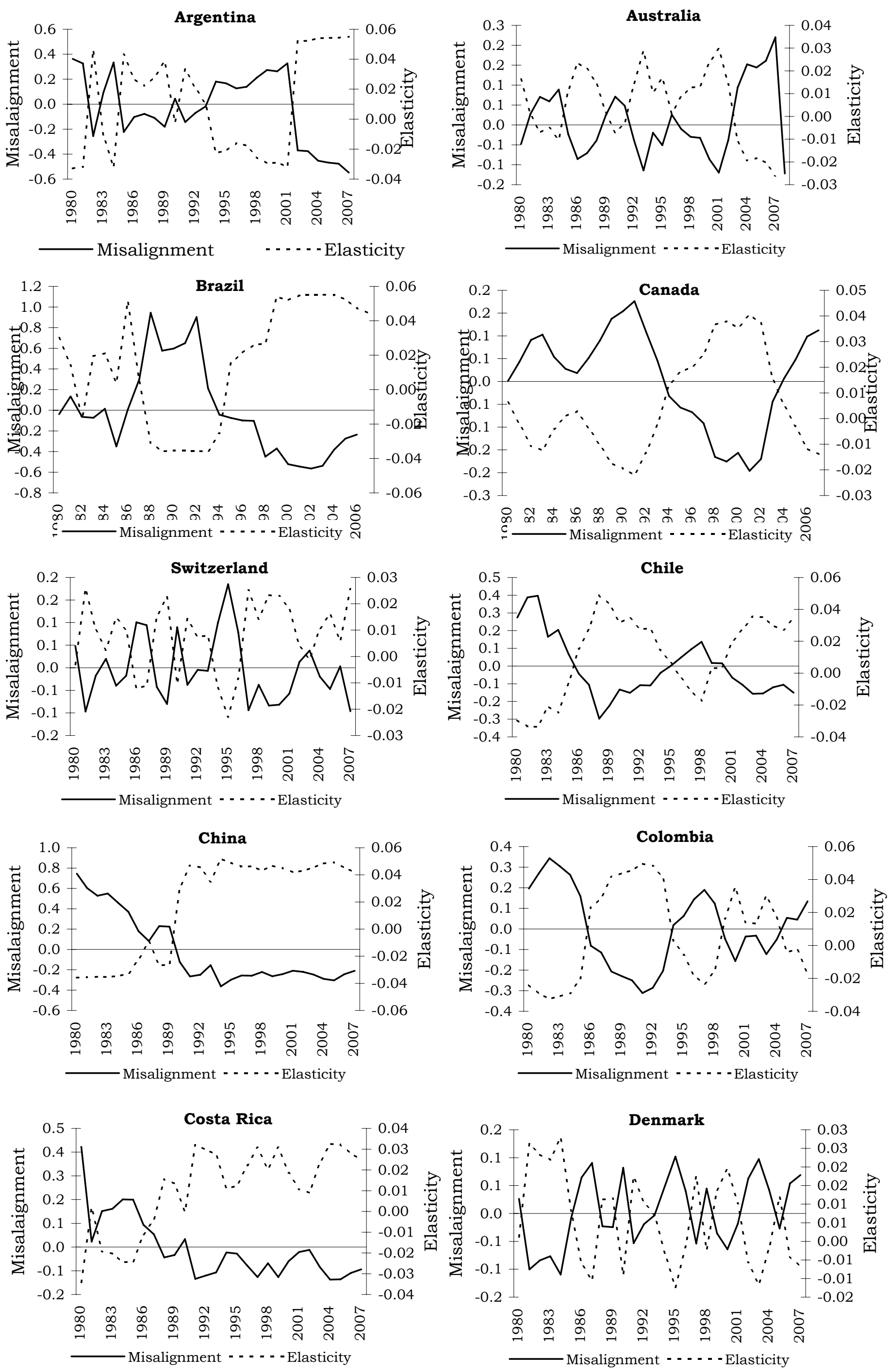

Figure 2 – Real exchange rate misalignment and estimated elasticity (Argentina, Australia, Brazil, Canada, Switzerland, Chile, China, Colombia, Costa Rica, Denmark)

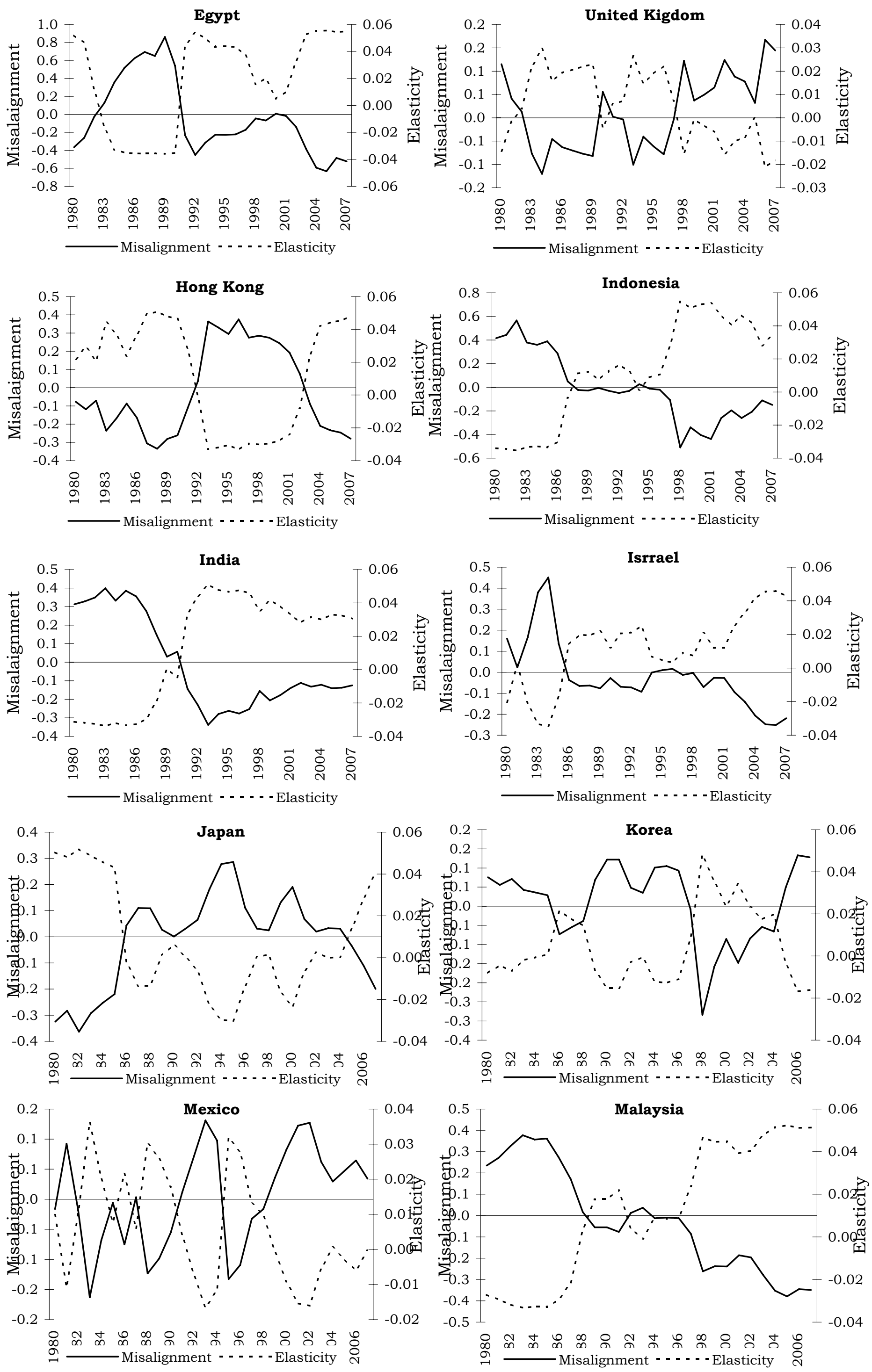

Figure 3 – Real exchange rate misalignment and estimated elasticity (Egypt, United Kingdom, Hong-Kong, Indonesia, India, Israel, Japan, Korea, Mexico, Malaysia)

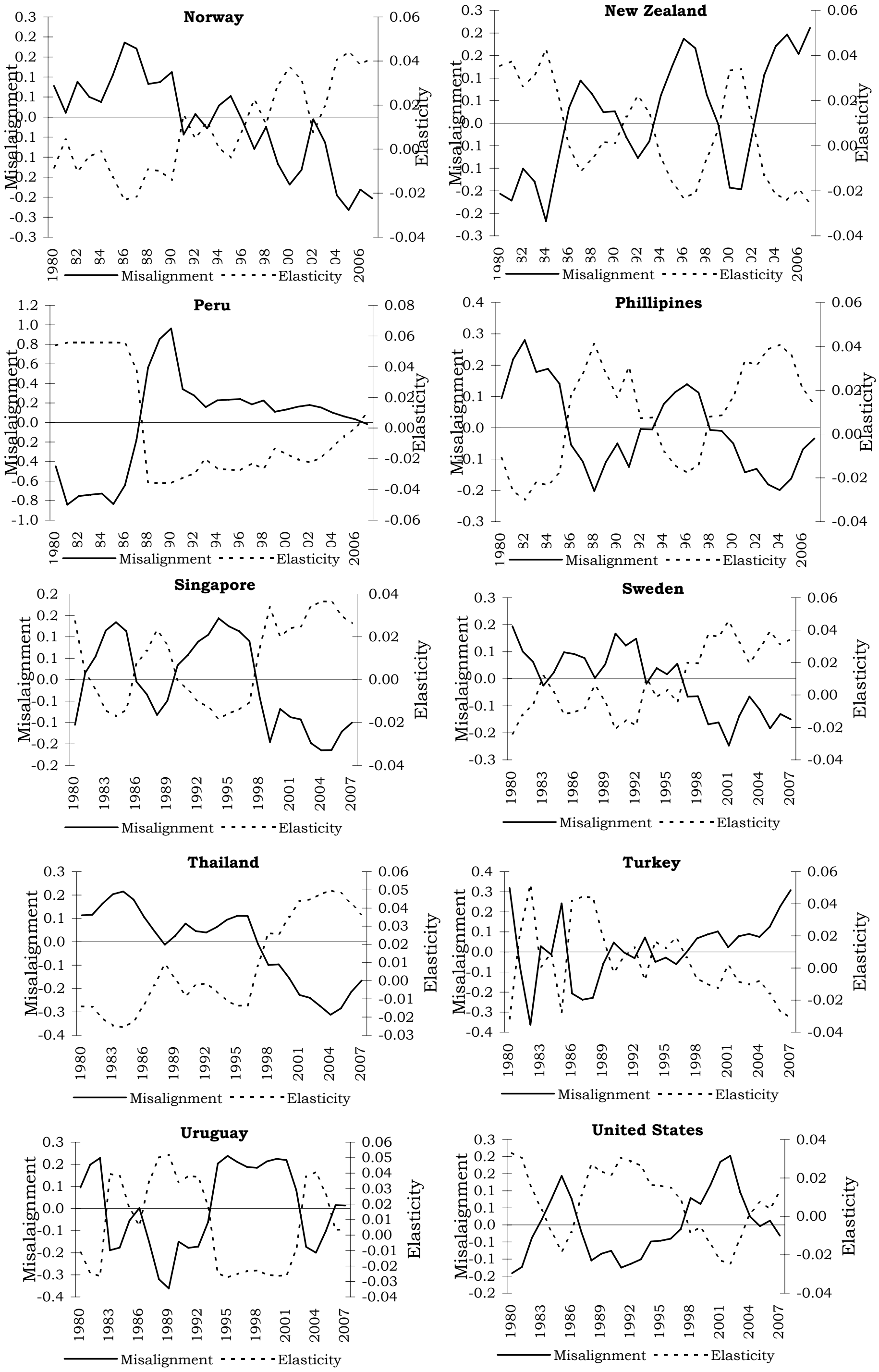

Figure 4 – Real exchange rate misalignment and estimated elasticity (Norway, New Zealand, Peru, Philippines, Singapore, Sweden, Thailand, Turkey, Uruguay, Euro area, United States)

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